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Im Auftrag

For the President of the European Patent Office

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A method of manufacturing a wafer

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A Method of Manufacturing a Wafer

The present invention relates to a method of manufacturing a wafer, in which a heterogeneous material compound is split at a pre-determined splitting area of the compound, and the compound is subject to a thermal treatment.

Heterogeneous material compounds or heterostructures having a thin layer attached to a receiver substrate with a different thermal expansion coefficient have attained considerable industry attention in the fields of microelectronics, optoelectronics and micromechanics. Such structures can be fabricated using deposition processes based on electroplating, evaporation, spinning, etc. In other approaches, a bulk material is bonded to a receiver substrate and thereafter thinned down, either by a chemical mechanical polishing or by etching of the material. These methods mostly have a very low efficiency due to a lot of process steps and the resulting structures often cannot be produced with the required quality.

US 5,877,070 proposes a method of manufacturing a wafer of the above-mentioned type. This method uses a modified variant of a so-called Smart-cut® process to transfer a thin film onto a hetero-substrate. Characteristic steps of this process are schematically shown in Figs. 18a to 18c.

As shown in fig. 18a, a donor wafer 91 and a receiver wafer 92 of materials with different thermal expansion coefficients are provided. With reference to fig. 18b, the donor wafer 91 is implanted through its surface 93 with ions 96, creating a pre-determined splitting area 95 at or in the vicinity of a certain implantation depth *d* of the donor wafer 91.

Then, the implanted donor wafer 91 is annealed using a tempering device 90, as shown in fig. 18c. This annealing step directly after the implanting step results in a weakening of the pre-determined splitting area 95 due to formation and growth of micro-cracks in the implanted region. The temperature used at that annealing step must be adjusted at a relatively low value to prevent the formation of surface blisters induced by ion implantation, which would prevent subsequent bonding of the donor substrate with a second substrate. Therefore, the weakening effect resulting from this annealing step is relatively minor.

As shown in fig. 18d, the implanted and annealed donor wafer 91 is bonded with the receiver wafer 92 at the implanted surface 93 of the donor wafer 91 resulting in a heterogeneous wafer compound 99. This is followed by a second thermal treatment in a tempering device 90', as shown in fig. 18e. The second thermal treatment causes further growth, overlapping and coalescence of the micro-cracks induced by ion-implantation, which split the wafer compound 99 at the pre-determined splitting area 95 when an energy corresponding to a budget of thermal splitting is reached for the respective compound.

The budget of thermal splitting is a certain thermal budget corresponding to the limit for thermal splitting or cleaving of a material, which is 100% of the necessary energy at which splitting occurs thermally. The used temperature-time-dependency of the budget of thermal splitting follows the Arrhenius Law in which the reciprocal of the annealing time is proportional to the exponent of the reciprocal of the annealing temperature. The budget of thermal splitting of heterogeneous bonded structures is dependent on a number of material, environmental and technological parameters like the kind of material, implantation conditions and bonding conditions.

The above described second thermal treatment must be carried out at relatively low temperature at which the bonded wafer pair suffers from degradation due to the different thermal expansion coefficients of the materials of the wafers 91, 92. This leads to an expanded annealing time for splitting of the wafer compound 99 to transfer a thin layer 97 of the donor wafer 91 to the receiver wafer 92.

In a further approach, US-5-877-070 suggests an additional implantation step using a boron implantation to lower the detachment temperature. This method results in disadvantageous boron doping of the surrounding layers and is, especially due to the additional implantation step, expensive and time-consuming.

Another attempt, which has been presented for instance by Aspar et al in the Proceedings of MRS, 1998, uses a high dose hydrogen implantation to facilitate splitting of a wafer of a heterogeneous wafer compound at the implanted area in an annealing step. However, this high dose ion implantation raises the cost of manufacture.

FR-A-2-755-537 describes a method to transfer a thin layer to a heterostructure in which an implanted substrate is thinned down after bonding of this substrate with another substrate to limit a sudden stress variation during thermal splitting causing indefinite breakage of the compound. This method causes an additional process step and results in a significant material consumption because the removed material is lost.

FR-A-2-748-851 discloses a method to detach a structure at lower temperatures using a combination of a heat treatment and mechanical efforts such as traction, shearing or bending forces. Such forces can be applied with a tool, a fluid or with another source of mechanical energy, for instance, as described in EP 0 977 242 A2, with a jet.

WO 01/80308 A2 proposes an injection of energy pulses, such as laser pulses, into a structure with an embrittled zone to transfer a thin layer of silicon onto a SiO_2 substrate.

It is the object of the present invention to provide a method of manufacturing a wafer with an easy and effective splitting of a heterogeneous material compound at a reduced risk of an undefined breaking of the compound.

The object is solved by a method of the above-mentioned type characterised in that the thermal treatment comprises an annealing of the compound which is stopped before a splitting of the compound; and an irradiation of the compound with photons to obtain a splitting of the compound at the pre-determined splitting area.

By the annealing step, the pre-determined splitting area of the compound can be pre-fragilised thermally but not thermally split yet at said area. This way, a certain amount of thermal energy is already provided to this pre-determined splitting area in the annealing step. The irradiation step provides the additional amount of thermal energy needed to split the compound at the pre-determined and pre-fragilised splitting area in an easy but efficient way. It allows the localisation of additional thermal energy at the pre-determined splitting area, whereby a risk of deformation due to annealing which could lead to damage or degradation of the compound can be reduced. With the irradiation step it is possible to obtain split parts of the compound relatively quickly, with good quality and very low risk of an indefinite destruction or degradation of the heterogeneous material compound.

Since both steps, the annealing step and the irradiation step, are performed after the formation of the compound, they can be very easily combined and adjusted to each other, resulting in reduced wafer handling and increased efficiency of the process.

In a favourable embodiment of the invention, the annealing step is performed at an energy of up to 99%, preferably at about 70% to 99% of an energy of a budget of thermal splitting at which the compound can split. This way, in the annealing step an optimum energy can be applied to the compound to pre-fragilise the compound. Therefore, the following irradiation step must only apply a relatively small amount of energy to the compound to make it possible that the compound can be split very quickly and in a smooth way.

It is furthermore advantageous to apply the photons with a wavelength absorbable by at least one of the compound materials. This allows a heat formation in the compound during the irradiation step, which can be used for a selective local heating of the pre-determined splitting area for a short time to provide there a thermal energy for splitting and to minimise a risk of deformation of the compound.

In a favourable example of the invention, the irradiation is performed through a receiver substrate being a part of the heterogeneous material compound and serving to receive a part of a donor material of the compound in which the pre-determined splitting area is formed. With this method, photons can go through the receiver substrate and can then be absorbed in the donor substrate, leading to a direct heating of the pre-determined splitting area for splitting.

In another example of the invention, the irradiation is performed through a donor substrate being a part of the heterogeneous material compound, in which the pre-determined splitting area is formed. Using this method, the photons can go through the donor substrate and can be absorbed in another part of the heterogeneous material compound next to the donor substrate, such as a receiver substrate, to heat up the pre-determined splitting area in the donor substrate indirectly, via conduction.

According to a favourable variant of the invention, a heat sink is applied at or in the vicinity of a material of the heterogeneous material compound, which has the higher thermal expansion coefficient of said compound. By this method, it is possible to ensure that the

material with the higher thermal expansion coefficient heats up only to a level below a threshold temperature above which the heterogeneous material compound could be damaged in an undefined manner.

Preferably, the annealing step comprises an irradiation with photons. This enables an efficient heating of the heterogeneous material compound in the annealing step, leading to a good pre-weakening effect at the pre-determined splitting area.

In a particularly advantageous embodiment of the invention, the annealing step and the irradiation step are performed with one equipment. This method reduces the handling requirements for splitting of the heterogeneous material compound and can shorten the necessary processing time.

In a beneficial variant of the invention, the photons are selected from a group consisting of non-coherent light or laser light. This makes it possible to get a good energy supply to the heterogeneous material compound wherein a broad variety of light sources can be used.

According to another advantageous embodiment of the invention, the irradiation is provided two-dimensionally over a surface of the heterogeneous material compound. This allows a good energy supply to the whole compound in a relatively short time. Furthermore, with this method it is possible to obtain a homogenous heating up of the compound, resulting in a uniform splitting of the pre-determined splitting area upon such irradiation.

According to a further embodiment of the invention, the photons are scanned over the compound. This method allows a continuous heating up of the compound which can cause a gradual expansion of a splitting front at the pre-determined splitting area in the compound, leading to very good splitting results.

In a yet further preferable embodiment of the invention, the irradiation applies a thermal shock to the heterogeneous material compound for splitting. The thermal shock provides both thermal and mechanical energy to initiate a crack propagation along the pre-determined splitting area, causing a very quick but very well-defined splitting of the compound. The thermal shock can be applied to influence thermally only the material

region of the pre-determined splitting area so that the residual part of the heterogeneous material compound remains unimpaired.

According to a further advantageous variant of the invention, the compound is cooled down to a room temperature of about 18°C to 25°C between the annealing step and the irradiation step. This has the advantage that the temperature of the heterogeneous material compound only increases locally at the pre-determined splitting line, whereas the temperature of the overall structure is maintained at room temperature. This aids in preventing any undefined breaking or formation of other defects in the compound.

According to a yet further advantageous example of the invention, the irradiation step is performed during a period in which the compound cools down from the temperature of the annealing step to a room temperature, and in which the compound has a temperature below a threshold temperature above which undefined damage of the compound can occur. This method makes it possible to split the compound in a defined way within a reduced process time.

It is furthermore advantageous to perform the irradiation with a Xenon lamp and/or a Halogen lamp. With a Xenon lamp and/or a Halogen lamp, photons with a short wavelength such as a blue or UV-irradiation can be applied to the heterogeneous material compound, which is especially of interest when at least one of the compound materials is transparent to that wavelength, while another compound material can absorb these photons. This permits selective heating of locally defined regions of the heterogeneous material compound.

According to a specific embodiment of the invention, a selective wavelength or spectrum of the irradiation is applied by using an irradiation filter. With the filter, a specific wavelength or spectrum, being advantageous for an effective treatment of the wafer, can be applied.

Specific embodiments of the present invention will become more apparent from the following detailed description with reference to the accompanying drawings, in which:

Fig.1 schematically shows typical steps before a splitting of the heterogeneous material compound according to an embodiment of the present invention;

Fig. 2 schematically shows an annealing step of a method according to an embodiment of the present invention;

Fig. 3 shows an irradiation step of a method according to a first embodiment of the present invention;

Fig. 4 schematically shows a temperature profile of the structure of fig. 3;

Fig. 5 schematically shows an irradiation step of a method according to a second embodiment of the present invention;

Fig. 6 schematically shows a temperature profile of the structure of fig. 5;

Fig. 7 schematically shows an irradiation of a method according to a third embodiment of the present invention;

Fig. 8 schematically shows a temperature profile of the structure of fig. 7;

Fig. 9 schematically shows an irradiation of a method according to a fourth embodiment of the present invention;

Fig. 10 schematically shows a temperature profile of the structure of fig. 9;

Fig. 11 schematically shows a temperature-time diagram of a method according to a fifth embodiment of the present invention;

Fig. 12 schematically shows a temperature-time diagram of a method according to a sixth embodiment of the present invention;

Fig. 13 schematically shows a temperature-time diagram of a method according to a seventh embodiment of the present invention;

Fig. 14 schematically shows a temperature-time diagram of a method according to an eighth embodiment of the present invention;

Fig. 15 schematically shows a temperature-time diagram of a method according to a ninth embodiment of the present invention;

Fig. 16 schematically shows a crack propagation in a compound upon a thermal shock at a centre of the compound;

Fig. 17 schematically shows a crack propagation in a compound upon a thermal shock at an edge of the compound; and

Fig. 18 schematically shows a prior art technique for manufacturing a wafer, in which a heterogeneous material compound is split.

Fig. 1 schematically shows initial steps for preparing a heterogeneous material compound 9. As shown in Fig. 1a, two substrates 1, 2 with different thermal expansion coefficients, are used. The substrates 1, 2 are preferably wafers but can be of any kind of substrate, such as layers, platelets, chips, compounds, etc. In principle, any kind of material can be used for substrates 1, 2; preferably the substrates 1, 2 are of silicon, silicon oxide, synthetic quartz or fused silica, silicon carbide, A_{III}-B_V semiconductors, such as gallium nitride, gallium arsenide or indium phosphide, SiGe, diamant, sapphire or silicon nitride. The substrates 1, 2 have surfaces 3, 4 which will be brought together later.

With reference to fig. 1b, the substrate 1 is implanted through the surface 3 with ions or ion clusters, such as hydrogen ions 6. The implanted ions 6 form a maximum ion concentration in the substrate 1 at or in the vicinity of a certain depth *d*, around which a pre-determined splitting area 5 is formed.

The pre-determined splitting area 5 divides the substrate 1 into a thin region 7 above this area 5 and a residual part 8 below this area 5.

As shown in fig. 1c, the implanted substrate 1 and the substrate 2 are bonded together at a bonding interface 10, forming a heterogeneous material compound 9. The bonding is

accomplished in such a way that the thin region 7 of the donor substrate 1 is bonded with the receiver substrate 2.

Fig. 2 schematically shows an annealing step of a method according to an embodiment of the present invention. In the annealing step, the heterogeneous material compound 9 of fig. 1c is tempered in a furnace 11 or another tempering device to weaken the pre-determined splitting area 5. During annealing, a degree of energy is applied to the compound 9 which corresponds to an energy of up to 99%, preferably about 70% to 99% of a budget of thermal splitting at which splitting of the compound 9 occurs thermally.

The amount of energy applied is dependent on a number of material, environmental and technological parameters, like the kind of materials, implantation conditions, and bonding conditions of the respective heterogeneous material compound.

In another embodiment of the present invention, the annealing step can be performed with an irradiation of the compound 9.

The supply of energy to the heterogeneous material compound 9 during the above annealing step leads to a weakening of the structure at the pre-determined splitting area 5. This effect is independent of whether thermal energy is supplied by a furnace or an irradiation. The micro-cavities induced by ion-implantation are activated by the thermal energy and grow. The annealing step is stopped before a splitting of the compound.

Figs. 3 to 10 schematically show irradiation steps and temperature profiles according to several embodiments of the present invention. In each case, the irradiation step provides at least that additional amount of thermal energy to the structure which is necessary to split the respective compounds at the pre-determined splitting area 5. The irradiation step provides a local heating of the pre-determined splitting area 5. The local heating activates the pre-determined splitting area 5, so that the risk of deformation due to annealing which could lead to damage of the compound will be reduced.

Fig. 3 schematically shows an irradiation step according to a first embodiment of the present invention which can be applied to the pre-annealed heterogeneous material compound 9 of fig. 2. In that irradiation step, photons 12 are irradiated through the receiver

substrate 2 which is transparent to the irradiation. The photons 12 are absorb d within a few microns in the donor substrate 1. By this method, the region at and/or near the pre-determined splitting area 5 can be heated up directly, due to the direct thermal heating of the donor substrate 1.

Fig. 4 schematically shows the temperature profile of the structure shown in fig. 3, in which the temperature T is shown versus a thickness *d* of the heterostructure during the irradiation, according to the first embodiment. A maximum temperature T_{max} of the structure is achieved at and/or near the pre-determined splitting area 5, wheras the temperature gradually decreases starting from this pre-determined splitting area 5 to the outer surfaces of the heterogeneous material compound 9.

Fig. 5 schematically shows an irradiation step according to a second embodiment of the present invention which can be applied to the pre-annealed heterogeneous material compound 9 as shown in fig. 2. In this embodiment, the photons 12 go through the donor substrate 1 and are absorbed within a few microns in the receiver substrate 2, heating up this area. Then, the implanted pre-determined splitting area 5 in the donor substrate 1 is indirectly heated up via conduction.

Fig. 6 schematically shows a temperature distribution in the structure shown in fig. 5, in which the temperature T is shown versus a thickness *d* of the heterostructure, during the irradiation of the second embodiment. A maximum temperature T_{max} of the structure is achieved in the receiver substrate 2 near the interface 10 between the donor substrate 1 and the receiver substrate 2. The region with the maximum temperature T_{max} indirectly heats up the pre-determined splitting area 5 over the interface 10 resulting in an increased temperature T_{sa} at the pre-determined splitting area 5.

Fig. 7 schematically shows a method according to a third embodiment of the present invention. On a back side of the donor substrate 1, a heat sink 13 is applied. This heat sink 13 can be any cooling device which is able to cool the donor substrate 1. In this method, the photons 12 go through the receiver substrate 2 and are absorbed at the pre-determined splitting area 5 in the donor wafer 1. In the embodiment shown, the donor wafer 1 has a higher thermal expansion coefficient than the receiver substrate 2. Due to the cooling effect

of th heat sink 13, the donor substrate 1 does not heat up above a threshold temperature T_{Thr} above which the structure would break in an undefined manner.

Fig. 8 schematically shows a temperature distribution in the structure shown in fig. 7, in which the temperature T is shown versus the thickness *d* of the heterostructure, during the irradiation of the third embodiment. As already mentioned with reference to the first embodiment of the present invention shown in fig. 3, a maximum temperature T_{max} is reached by the method shown in fig. 7 at the pre-determined splitting area 5 in the donor substrate 1. The heat sink 13 which is applied on the back side of the donor substrate 1 prevents a heating up of the whole donor substrate 1, so that the heated up area is concentrated on the region at and near the pre-determined splitting area 5 in the donor substrate 1. This results in a very effective weakening at the pre-determined splitting area, whereas the residual part of the donor substrate 1 is not heated up above a critical threshold temperature T_{Thr} at which the structure would break in an undefined manner.

Fig. 9 schematically shows a fourth embodiment of the present invention. In this embodiment, the receiver substrate 2 has the higher thermal expansion coefficient in comparison to the donor substrate 1. In this case, a heat sink 13 is applied on the back side of the receiver substrate 2. The photons 12 go through the donor substrate 1 and are absorbed within a few microns of the receiver substrate 2, heating up this area. This leads to an indirect heating up of the pre-determined splitting area 5 in the donor substrate by the heated-up area next to the interface 10 between the receiver substrate 2 and the donor substrate 1.

As shown in Fig. 10, where a temperature distribution T versus the thickness *d* of the structure shown in fig. 9 is given, the heat sink 13 prevents the heating up of the whole receiver substrate 2. This results in a heat concentration of the area near the interface 10, so that a maximum temperature T_{max} is achieved within a few microns in the receiver substrate 2, causing an indirect heating of the pre-determined splitting area 5 in the donor substrate 1.

Fig. 11 schematically shows a fifth embodiment of the present invention. The method comprises an annealing step 140 and an irradiation step 150, 160. In the annealing step, a heterogeneous material compound such as the structure 9 shown in fig. 1c is annealed, for

instance in a furnace or another tempering device, for an annealing time t_{ann}. In this step, the temperature T is increased in a relatively short time from a room temperature T_R to a temperature T_{Bmax1} which is slightly above a threshold temperature T_{Thr}. Then, the structure 9 is held at the elevated temperature T_{Bmax1} and is decreased after a period of time again to room temperature T_R. The annealing step 140 provides an energy of up to 99%, preferably about 70% to 99% of the energy of a budget of thermal splitting to the compound 9, leading to a pre-weakening of the pre-determined splitting area 5 of the heterogeneous material compound 9.

Subsequent to the annealing step 140, an irradiation step 150, 160 is applied to the heterogeneous material compound 9. The irradiation step can be performed in the same device as the annealing step or in another device 140. The irradiation step 150, 160 can be applied over the whole heterogeneous material compound 9 in a two-dimensional way. This leads to a complete and uniform heating of the whole compound 9 at one time. In another embodiment, the irradiation can be performed by a scanning over the compound. By this particular method, a gradual heating up of the compound 9 can be achieved.

For irradiation, any kind of light source such as non-coherent light or laser light can be used. In the embodiment shown, a Xenon lamp is used, whereas in another preferable embodiment a Halogen lamp can be used. Blue or UV-light is advantageous.

As shown in fig. 11, the irradiation results in different temperature-time courses 150, 160, in the heterogeneous material compound 9. The temperature-time course 150 is achieved in a bulk material of the heterogeneous material compound 9, which is far from the interface 10 between the donor substrate 1 and the receiver substrate 2. The maximum temperature T_{Bmax2} of this bulk material is much lower than the critical threshold temperature T_{Thr} at which the heterogeneous material compound 9 could break in an undefined manner.

As shown by the temperature-time course 160, only a region near the interface 10 between the donor substrate 1 and the receiver substrate 2 is heated above the threshold temperature T_{Thr}. This leads to a supply of the residual amount of energy necessary for thermal splitting, resulting in a further weakening of the pre-determined splitting area 5 of the heterogeneous material compound 9, finally causing an accurate splitting of the heterogeneous material compound 9 at this pre-determined splitting area 5.

Fig. 12 schematically shows a temperature-time course of a method according to a sixth embodiment of the present invention. In this method, a heterogeneous material compound such as the structure 9 shown in fig. 1c is heated up from a room temperature T_R in a relatively short time to a temperature T_{Bmax1} which is slightly above a critical threshold temperature T_{Thr}. Then, the structure 9 is held at this temperature T_{Bmax1} for a certain time and is subsequently further decreased to a temperature T_{Bmax2} which is below the threshold temperature T_{Thr}. At the temperature T_{Bmax2} which is reached after an annealing time t_{ann}, the heterogeneous material compound 9 is irradiated with photons 12 in a similar way to that described with reference to fig. 11. The photons cause the temperature-time course 161 at the interface 10 of the heterogeneous material compound 9 and the temperature-time course 151 in a bulk material of the heterogeneous material compound 9.

As shown by the temperature-time course 161, the area near the interface 10 of the heterogeneous material compound 9 heats up to a temperature T_{IFmax} which is higher than the threshold temperature T_{Thr}. This heating of the interface is performed in a relatively short time t_{irr}. In this time t_{irr}, the bulk material of the heterogeneous material compound 9 only heats up to a temperature T_{Bmax2} which is lower than the threshold temperature T_{Thr}, preventing an undefined damaging of the heterogeneous material compound 9 during the irradiation step 151, 161.

Fig. 13 schematically shows a method according to a seventh embodiment of the present invention. In this method, a heterogeneous material compound such as structure 9 of fig. 1c undergoes an annealing step 140 which is similar to the annealing step shown and described with reference to fig. 11. After the annealing step 140 there follows an irradiation step 150, 162 for an irradiation time t_{irr}. The structure 9 is irradiated with photonic pulses 162, each of which induces a temperature T_{IFmax} at the interface 10 between the donor substrate 1 and the receiver substrate 2. These photonic pulses cause only a slight heating up of the bulk material of the heterogeneous material compound 9, as shown by the temperature-time course 150 of fig. 13. The bulk material reaches a temperature T_{Bmax2} which is much lower than the threshold temperature T_{Thr} at which the heterogeneous material compound could break in an undefined manner.

The photonic pulses 162 cause a favourable weakening of the pre-determined splitting area 5, leading to a good splitting at this area 5.

Fig. 14 schematically shows a method according to an eighth embodiment of the present invention. First, an annealing step 140 is performed which is similar to the annealing step shown and described with reference to figs. 11 and 13. In this annealing step, the pre-determined splitting area 5 is pre-weakened at an energy of up to 99%, preferably at about 70% to 99% of a budget of thermal splitting at which the heterogeneous material compound 9 can split. The further percentage of energy necessary for splitting is applied in the following irradiation step 163. There, a photonic pulse 163 with a relatively high intensity is performed in a relatively short time t_{irr}, leading to a thermal shock of the compound 9. By the pulse 163, only a region at and/or near the pre-determined splitting area 5 heats up to a temperature T_{Sh}. The residual bulk material of the heterogeneous material compound 9 remains at room temperature T_R so that the damaging of the heterogeneous material compound 9 in an undefined manner is prevented. The photonic pulse 163 results in a sufficient weakening of the pre-determined splitting area, causing a good splitting of the structure 9 along this pre-determined splitting area 5.

Fig. 15 schematically shows a method according to a ninth embodiment of the present invention. This method involves first applying an annealing step 140 to a heterogeneous material compound such as the structure 9 of fig. 1c, which is similar to the annealing step 140 shown and described with reference to figs. 11, 13 and 14. At the end of this annealing step 140, the heterogeneous material compound 9 is irradiated with photons 164 in a similar way to that described with reference to fig. 11 or as a photonic pulse or pulses. The irradiation is started during cooling of the heterogeneous material compound 9 in the annealing step, at a temperature at which the heterogeneous material compound 9 below a critical threshold temperature T_{Thr}. During irradiation, only a region at and/or near the interface 10 between the donor substrate 1 and the receiver substrate 2 is heated up to a relatively high temperature T_{Sh} which is much higher than the threshold temperature T_{Thr}. The residual part of the heterogeneous material compound does not heat up above this threshold temperature T_{Thr}. At the end of this combined annealing and irradiation, 100% of the necessary energy corresponding to 100% of the budget of thermal splitting is reached, resulting in a high quality splitting of the heterogeneous material compound 9 at the pre-determined splitting area 5.

With reference to figs. 16 and 17, the photonic treatments or shocks shown in figs. 14 and 15 can be applied locally, for instance at a centre of a substrate, as shown in fig. 16, or at an edge of a substrate as shown in fig. 17. In another embodiment of the invention, a thermal shock can be applied over the whole material compound.

The duration and the energy of the applied thermal shocks depend on the properties of the material used in the heterogeneous material compound 9.

The thermal shock provides both thermal and mechanical energy in initiating crack propagation through the pre-determined splitting area 5. Such thermal shocks have the advantage that they can be well-assimilated by the pre-determined splitting area 5. By using the thermal shock, a part of the heterogeneous material compound with a higher thermal expansion coefficient can be maintained at a relatively low temperature, wherein the pre-determined splitting area heats up and leads to a good splitting, whereas the residual part of the material compound is not damaged.

Claims

1. A method of manufacturing a wafer in which a heterogeneous material compound (9) is split at a pre-determined splitting area (5) of the compound (9), and the compound (9) is subject to a thermal treatment
characterised in that
the thermal treatment comprises:
an annealing (140, 141) of the compound (9), which is stopped before a splitting of the compound (9); and
an irradiation (150, 151, 153; 160, 161, 162, 163, 164) of the compound (9) with photons (12) to obtain a splitting of the compound (9) at the pre-determined splitting area (5).

2. The method of claim 1, **characterised in that** the annealing step (140, 141) is performed at an energy of up to 99%, preferably at about 70% to 99% of an energy of a budget of thermal splitting at which the compound (9) can split.

3. The method of at least one of claims 1 and 2, **characterised in that** the photons (12) are applied with a wavelength absorbable by at least one of the compound materials (1, 2).

4. The method of at least one of the preceding claims **characterised in that** the irradiation (150, 151, 153; 160, 161, 162, 163, 164) is performed through a receiver substrate (2) being a part of the heterogeneous material compound (9) and serving to receive a part of a donor material (1) of the compound (9) in which the pre-determined splitting area (5) is formed.

5. The method of at least one of the preceding claims **characterised in that** the irradiation (150, 151, 153; 160, 161, 162, 163, 164) is performed through a donor substrate (1) being a part of the heterogeneous material compound (9), in which the pre-determined splitting area (5) is formed.

6. The method of at least one of the preceding claims **characterised in that** a heat sink (13) is applied at or in the vicinity of a material (1, 2) of the heterogeneous

material compound (9), which has the higher thermal expansion coefficient of said compound (9).

7. The method of at least one of the preceding claims **characterised in that** the annealing step (140, 141) comprises an irradiation with photons (12).

8. The method of at least one of the preceding claims **characterised in that** the annealing step (140, 141) and the irradiation step (150, 151, 153; 160, 161, 162, 163, 164) are performed with one equipment.

9. The method of at least one of the preceding claims **characterised in that** the photons (12) are selected from a group consisting of non-coherent light and laser light.

10. The method of at least one of the preceding claims **characterised in that** the irradiation (150, 151, 153; 160, 161, 162, 163, 164) is provided two-dimensionally over a surface of the compound (9).

11. The method of at least one of claims 1 to 9 **characterised in that** the photons (12) are scanned over the compound (9).

12. The method of at least one of the preceding claims **characterised in that** the irradiation (163, 164) applies a thermal shock to the heterogeneous material compound (9) for splitting.

13. The method of at least one of the preceding claims **characterised in that** the compound (9) is cooled down to a room temperature (T_R) of about 18°C to 25°C between the annealing step (140, 141) and the irradiation step (150, 151, 153; 160, 161, 162, 163, 164).

14. The method of at least one of the preceding claims **characterised in that** the irradiation step (164) is performed during a period in which the compound (9) cools down from a temperature (T_{Bmax1}) of the annealing step (140) to a room temperature

(T_R), and in which the compound (9) has a temperature below a threshold temperature (T_{Thr}) at which an undefined damage of the compound (9) can occur.

15. A method of at least one of the preceding claims **characterised in that** the irradiation (150, 151, 153; 160, 161, 162, 163, 164) is performed with a Xenon lamp and/or a Halogen lamp.

16. A method of at least one of the preceding claims **characterised in that** a selective wavelength or spectrum of the irradiation is applied by using an irradiation filter.

Abstract

The present invention relates to a method of manufacturing a wafer in which a heterogeneous material compound is split at a pre-determined splitting area of the compound, and the compound is subject to a thermal treatment. It is the object of the present invention to provide an easy and effective method of splitting a heterogeneous material compound with a reduced risk of an undefined breaking of the compound. The object is solved by a method of the above-mentioned type characterised in that the thermal treatment comprises: an annealing of the compound which is stopped before a splitting of the compound; and an irradiation of the compound with photons in order to obtain a splitting of the compound at the pre-determined splitting area.

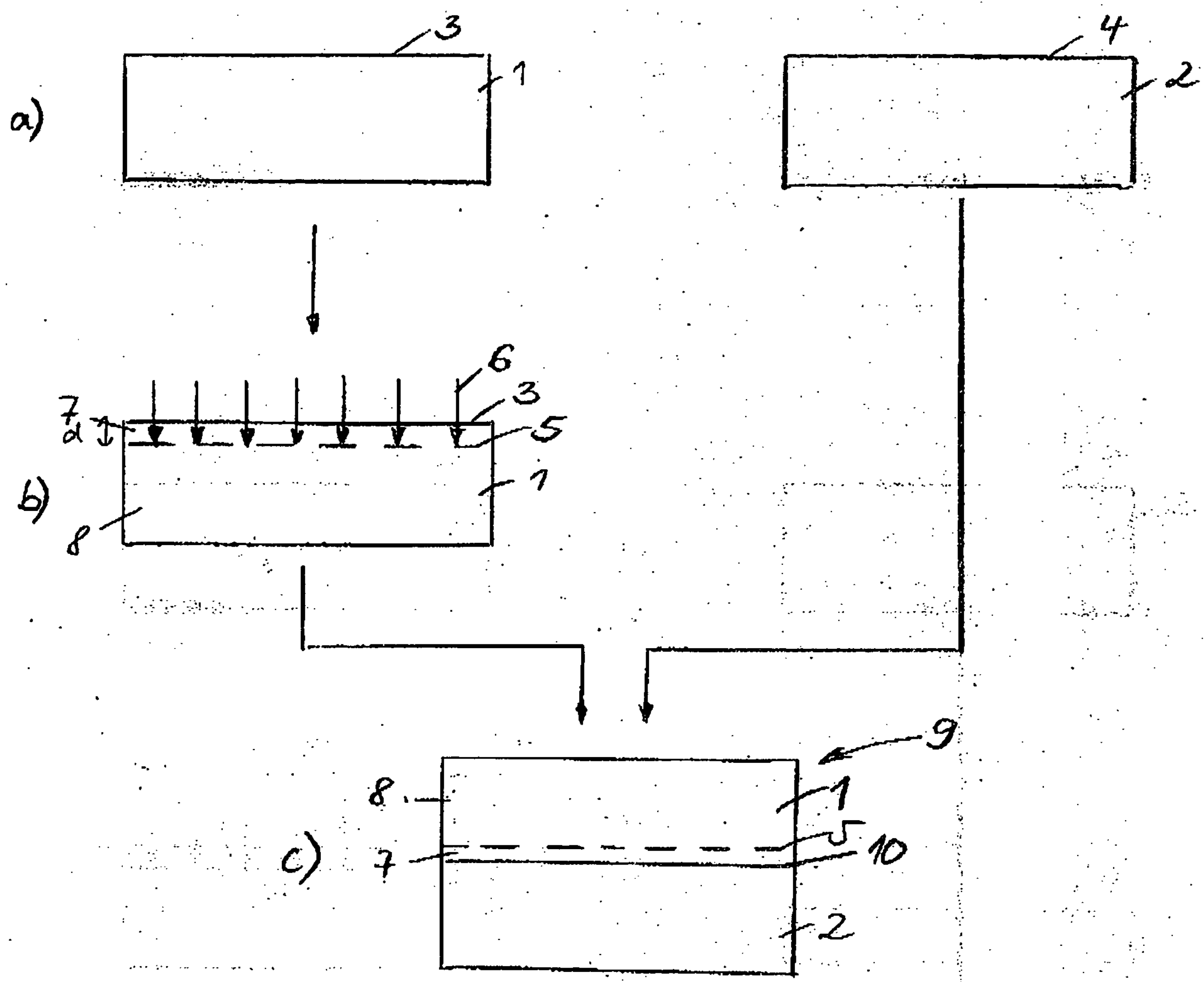


Figure 1

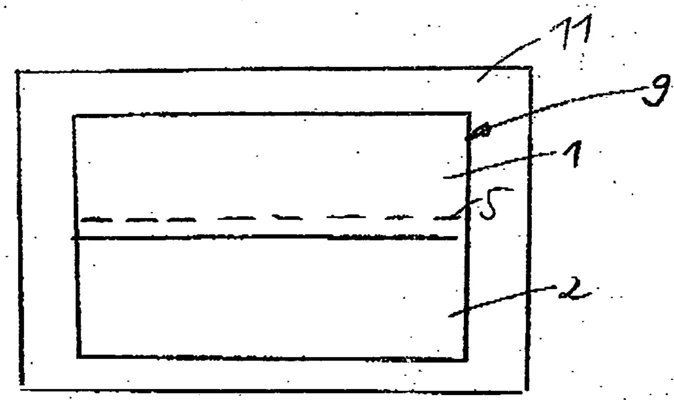


Figure 2

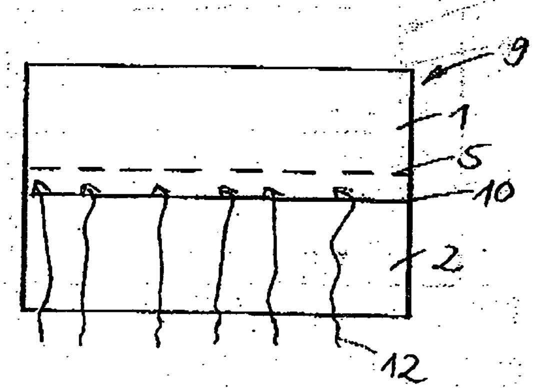


Figure 3

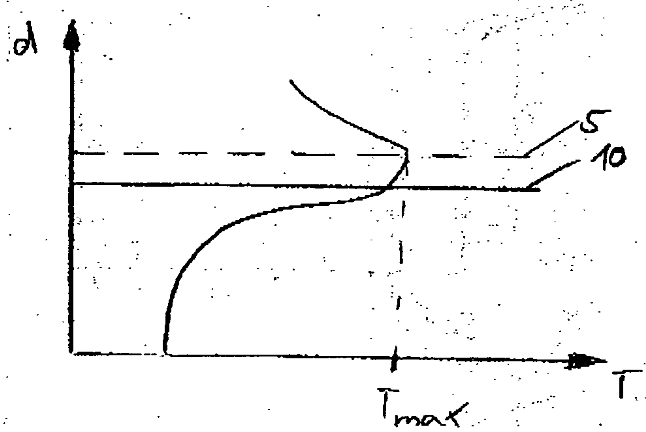


Figure 4

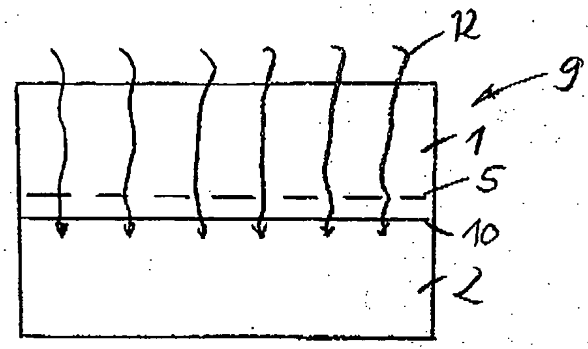


Figure5

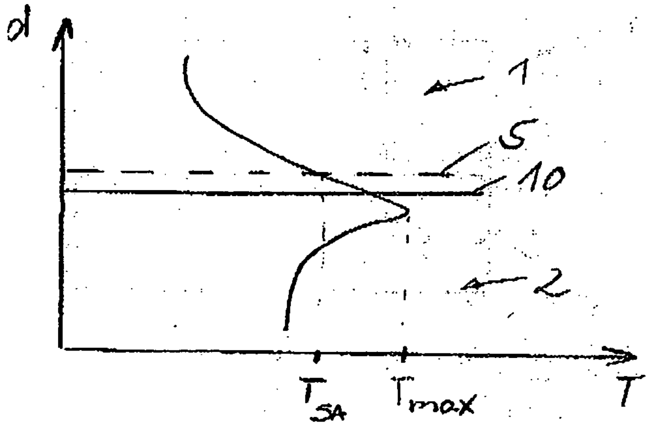


Figure6

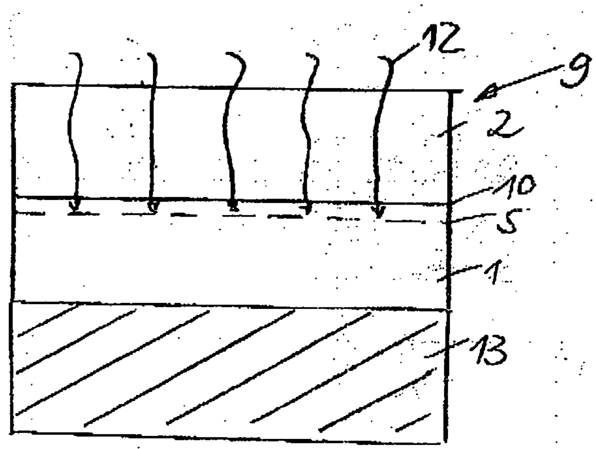


Figure7

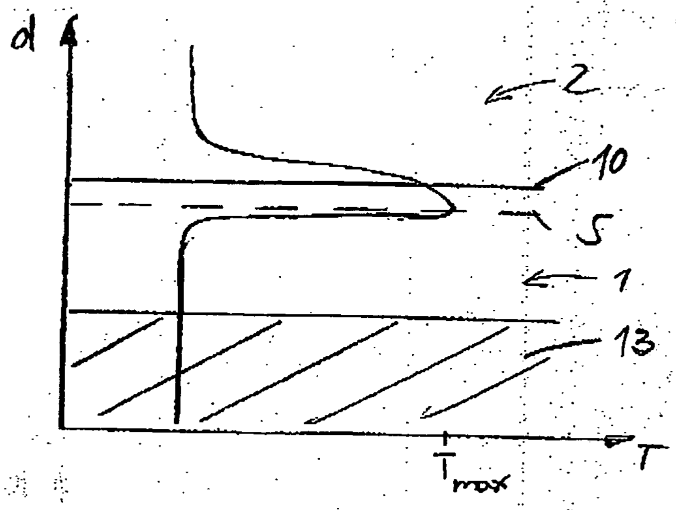
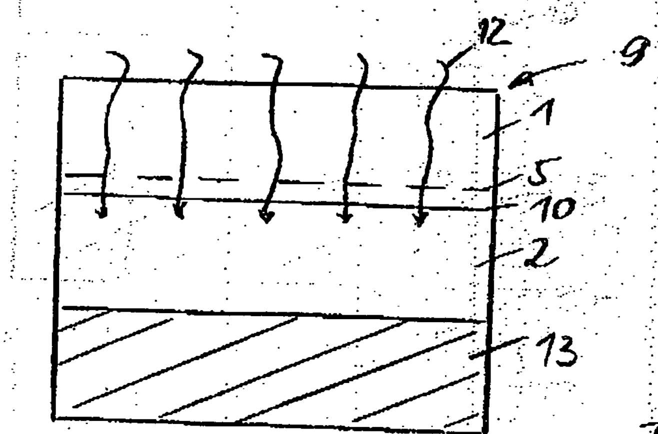


Figure8



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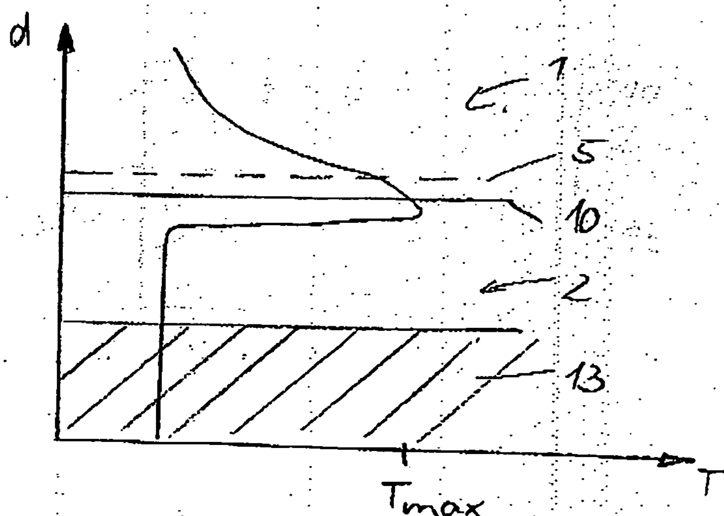
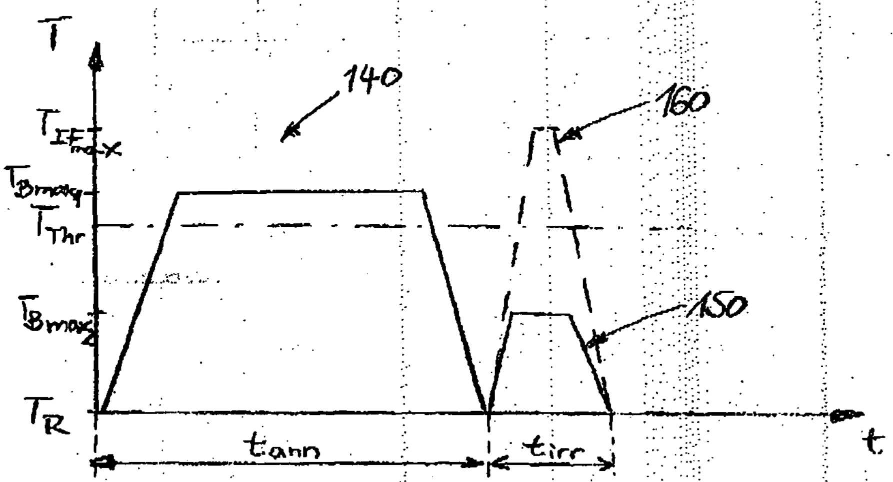


Figure10



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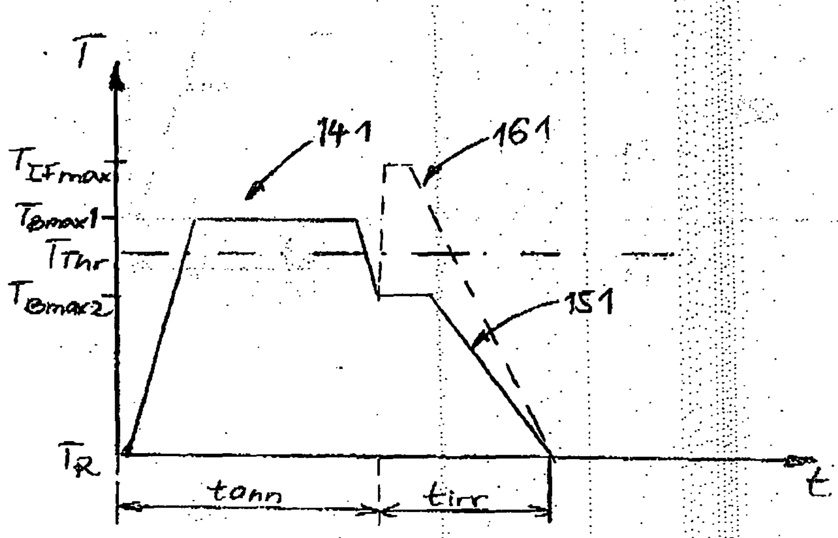

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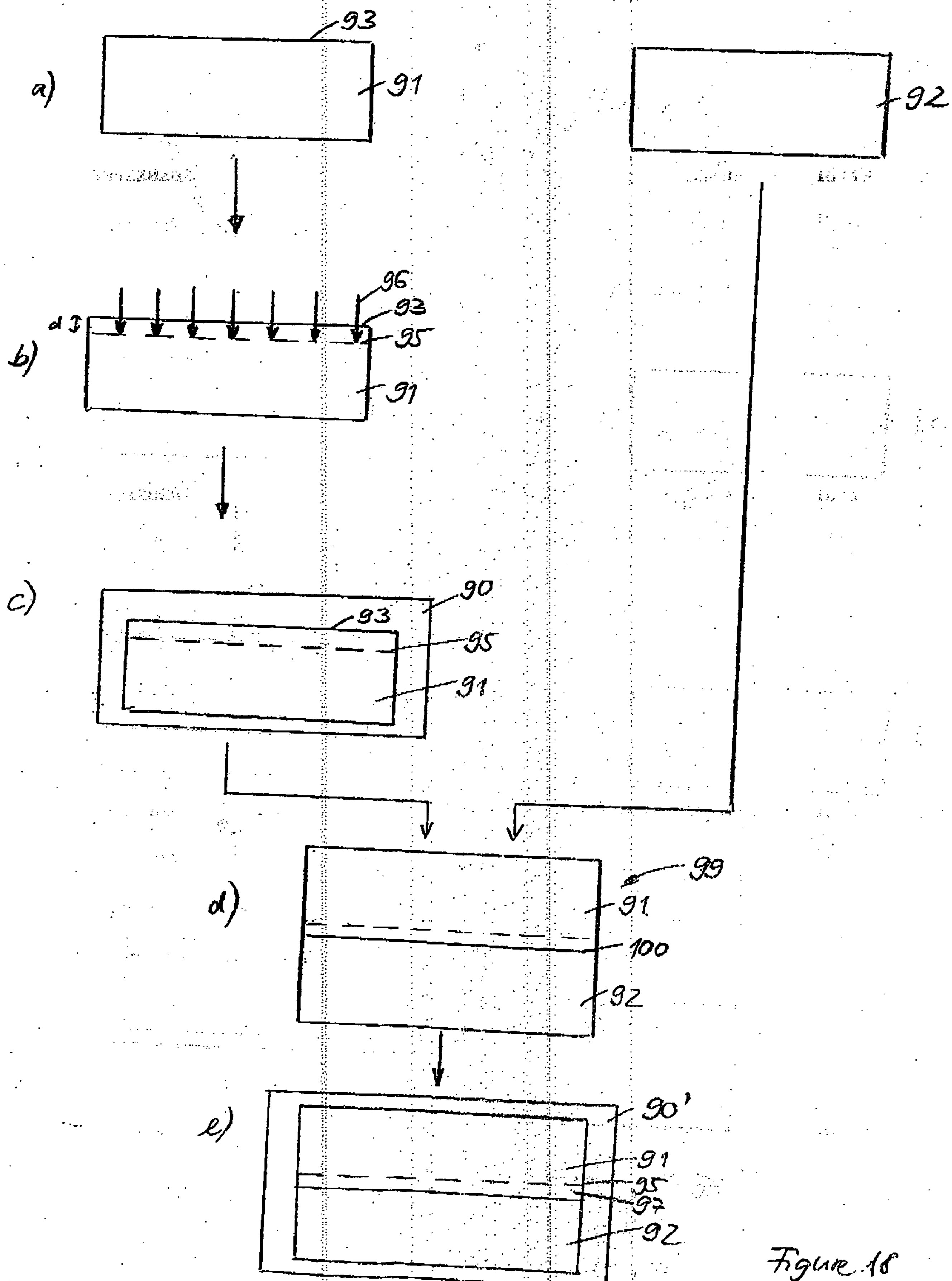

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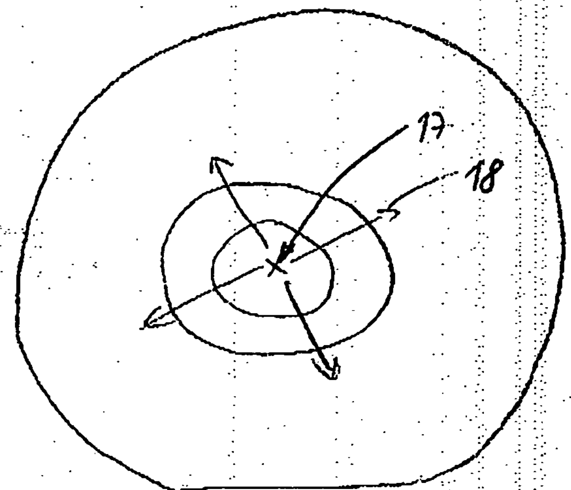

Figure 16

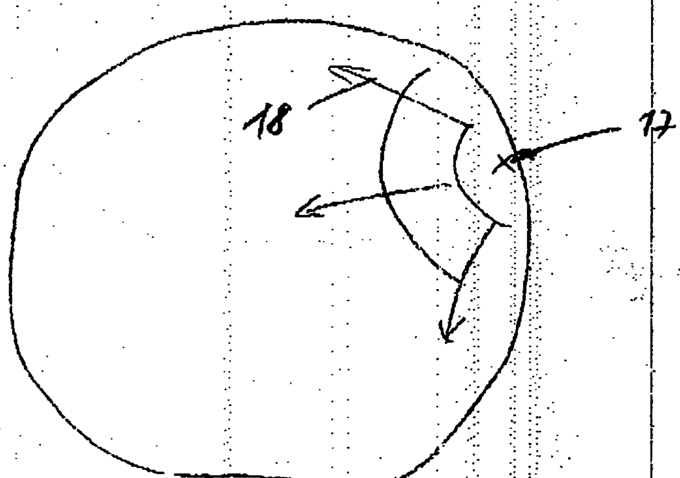

Figure 17

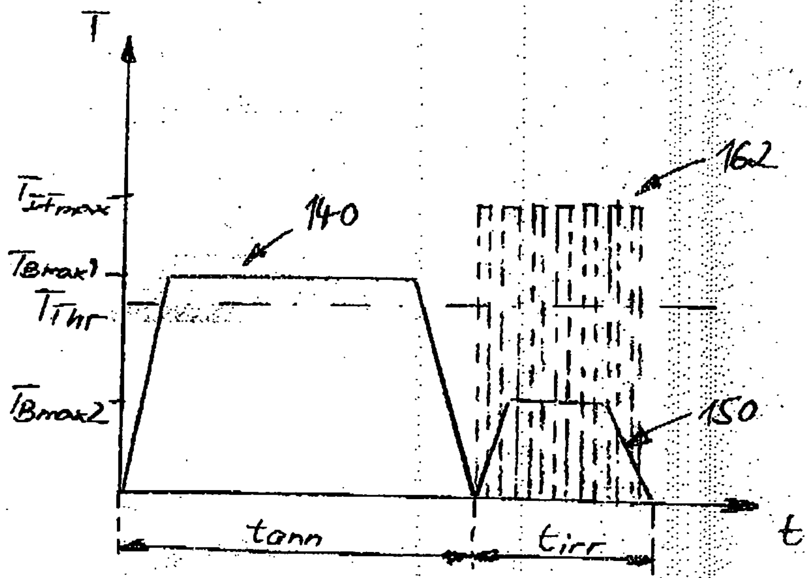

Figure 13

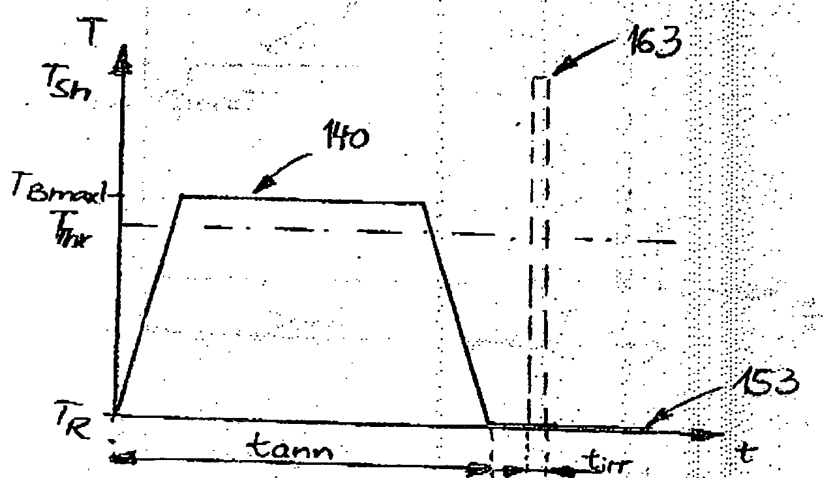

Figure 14

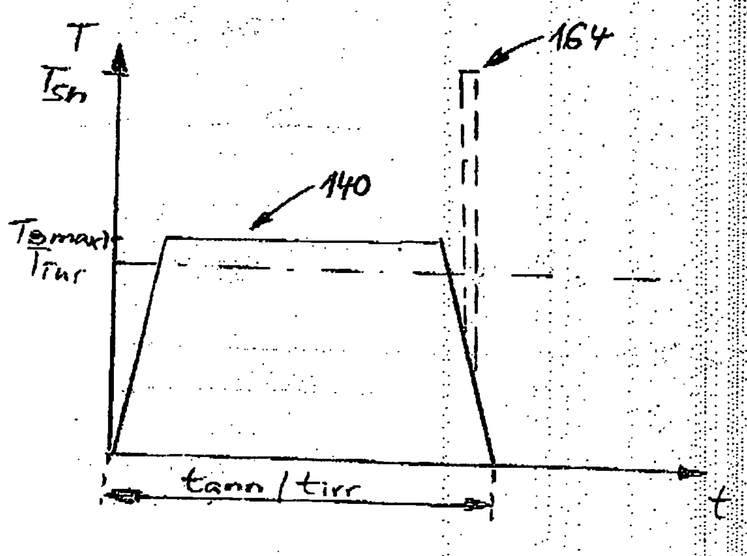

Figure 15